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Sampling and Analysis Plan to Support Recommendation for No Further Investigation of Petroleum Hydrocarbons at the Age Maintenance Area IRP Site SD-11

Beale Air Force Base
California

Prepared For

Air Force Center for Environmental Excellence
Technology Transfer Division
Brooks Air Force Base
San Antonio, Texas

and

9CES/CEV
Beale Air Force Base, California

December 1998

PARSONS
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FINAL

SAMPLING AND ANALYSIS PLAN TO SUPPORT RECOMMENDATION FOR NO FURTHER INVESTIGATION OF PETROLEUM HYDROCARBONS AT THE AGE MAINTENANCE AREA, IRP SITE SD-11

BEALE AIR FORCE BASE, CALIFORNIA

Prepared for:

Air Force Center for Environmental Excellence
Brooks Air Force Base, Texas

and

9 CES/CEV

Beale Air Force Base, California

December 1998

Prepared by:

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LIST OF ABBREVIATIONS AND ACRONYMS

µg/L	Micrograms per liter
1,2-DCA	1,2-Dichloroethane
1,2-DCE	1,2-Dichloroethene
AFB	Air Force Base
AFCEE	Air Force Center for Environmental Excellence
AGE	Aircraft Ground Equipment
AST	Aboveground storage tank
ASTM	American Society for Testing and Materials
bgs	Below ground surface
BTEX	Benzene, toluene, ethylbenzene, and xylenes
CAC	California Administrative Code
Cal/EPA	California Environmental Protection Agency
cfm	Cubic feet per minute
DLM	Designated Level Methodology
DOT	Department of Transportation
EAF	environmental attenuation factor
ES	Engineering-Science, Inc.
HVOC	Halogenated volatile organic compound
ID	Inside diameter
IRP	Installation Restoration Program
LCC	Laguna Construction Company, Inc.
LUFT	Leaking Underground Fuel Tank
MCLs	Maximum contaminant levels
mg/kg	Milligrams per kilogram
mg/L	Milligrams per liter
NFI	No further investigation
OD	Outside diameter
OVA	Organic vapor analysis
Parsons ES	Parsons Engineering Science, Inc.
PID	Photoionization detector
ppmv	parts per million, by volume
QC	Quality control
RBCLA	Risk-Based Cleanup Level Assessment
RWQCB	Regional Water Quality Control Board
SAI	Specialized Assays, Inc.
SAP	Sampling and Analysis Plan
SESOIL	Seasonal Soil Compartment Model
SVE	Soil vapor extraction
TCE	Trichloroethene
TOC	Total organic carbon
TPH	Total petroleum hydrocarbons
TVH	Total volatile hydrocarbons

TVHA	Total volatile hydrocarbon analyzer
USEPA	US Environmental Protection Agency
UST	Underground storage tank
VOCS	Volatile organic compounds
WET	Waste extraction test
WQGs	Water Quality Goals

SECTION 1

INTRODUCTION

This Sampling and Analysis Plan (SAP) presents the proposed scope of work to be conducted at Installation Restoration Program (IRP) Site SD-11, Aircraft Ground Equipment (AGE) Maintenance Area, at Beale Air Force Base (AFB), Yuba County, California. The AGE Maintenance Area includes a backfilled underground storage tank (UST) excavation and adjoining property which has been impacted by petroleum hydrocarbon releases to the subsurface. This SAP is intended to guide soil and soil vapor sampling at the AGE Maintenance Area to document the effectiveness of bioventing remediation of petroleum-hydrocarbon-contaminated soils and to support a no further investigation (NFI) recommendation for the three former USTs previously located at the site.

Since 1993, Beale AFB has participated in the U.S. Air Force Bioventing Initiative, sponsored by the Air Force Center for Environmental Excellence (AFCEE) at Brooks AFB, Texas in cooperation with the Air Force Armstrong Laboratory, the U.S. Environmental Protection Agency (USEPA), and Parsons Engineering Science, Inc. (Parsons ES, formerly Engineering-Science, Inc. [ES]). The initiative included conducting approximately 145 bioventing pilot tests at 56 Air Force installations throughout the country. These tests were designed to collect data on the effectiveness of bioventing for the remediation of soil contaminated with fuel hydrocarbons (e.g., jet fuel, diesel fuel, gasoline, and heating oil). In addition to Site SD-11, bioventing pilot tests and evaluations were also conducted a Sites 3 and 18 at Beale AFB (ES, 1993a, 1993b; AFCEE, 1994, 1995)

Results of the initiative at Beale AFB demonstrated that bioventing was an effective means for remediating petroleum-hydrocarbon-contaminated soils at the AGE Maintenance Area and the bioventing system was expanded in 1996 to treat other nearby soils that also had been impacted by past releases of petroleum products. Results from previous investigations at IRP Site SD-11 were reviewed in addition to the pilot-scale and expanded bioventing system results during preparation of this SAP.

This SAP consist of eight sections, including this introduction. Section 2 includes site description, history, and summaries of previous investigations and remediation activities. Section 3 includes the proposed SAP. Section 4 provides a discussion of the criteria that will be used to support a NFI recommendation for the former USTs and petroleum-hydrocarbon-contaminated soils within the AGE Maintenance Area. Analytical results from the sampling activities and recommendations will be presented in a results report as described in Section 5. A proposed schedule for the sampling activities and submittal of the results report is included in Section 6. Section 7 provides points of contact. Section 8 provides references cited in this SAP.

SECTION 2

SITE DESCRIPTION

2.1 SITE LOCATION AND HISTORY

The AGE Maintenance Area is located in the northwestern portion of Beale AFB (Figure 2.1), and is bounded by Arnold Avenue to the west and Curtis Street to the south (Figure 2.2). IRP Site SD-11 consists of those facilities in the AGE Maintenance Area, including Building 1225, three existing aboveground storage tanks (ASTs), two active oil/water separators, a small pump island, a backfilled UST excavation, paved vehicle parking areas, landscaped areas, and unlined drainage channels (Figure 2.2). Building 1086 which is located approximately 400 feet south of the AGE Maintenance Area also has been incorporated into IRP Site SD-11 (Laguna Construction Company, Inc. [LCC], 1998); however, this SAP does not address environmental contamination at this location.

Current and former facilities at IRP Site SD-11 have been used to support AGE maintenance activities for more than 30 years. These activities have included storage of gasoline, diesel, and JP-4 jet fuel in three former USTs connected to a fuel pump island. Identification numbers for the three former USTs are 1225.01, 1225.02, and 1225.03, but it is not known which individual tank contained the above-mentioned fuel products. Vehicle cleaning operations were historically performed at a washrack located near two former oil/water separators on the east side of the AGE Maintenance Area (individually referred to as Oil/Water Separator A and Oil/Water Separator A'). In addition, aircraft ground support vehicles have been stored and operated in the paved area south of Building 1225. The former USTs, former oil/water separators, and historic fueling, maintenance, and storage of support vehicles in this area are all identified as potential sources of subsurface contamination in the AGE Maintenance Area.

During previous site investigations, petroleum hydrocarbon and halogenated volatile organic compound (HVOC) contamination have been identified in site soil, soil vapor, and groundwater. Petroleum hydrocarbon contamination at the site is primarily the result of fuel releases from the former USTs. Releases of petroleum products during vehicle fueling, maintenance, and storage operations also represent potential sources of subsurface petroleum contamination. The presence of HVOC contamination at the site has been attributed to releases from the former oil/water separators (Gaudette, 1998; LCC, 1998).

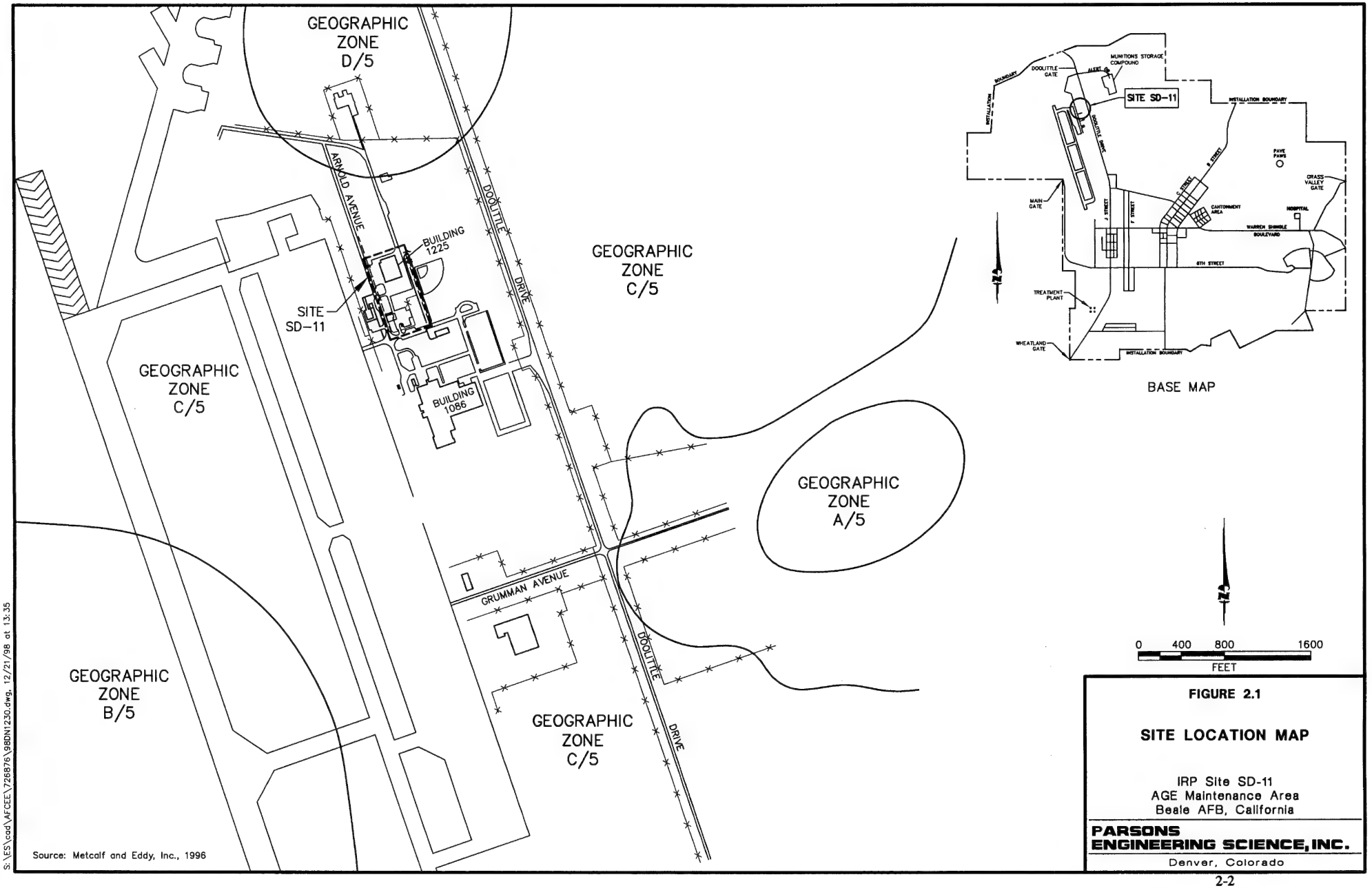

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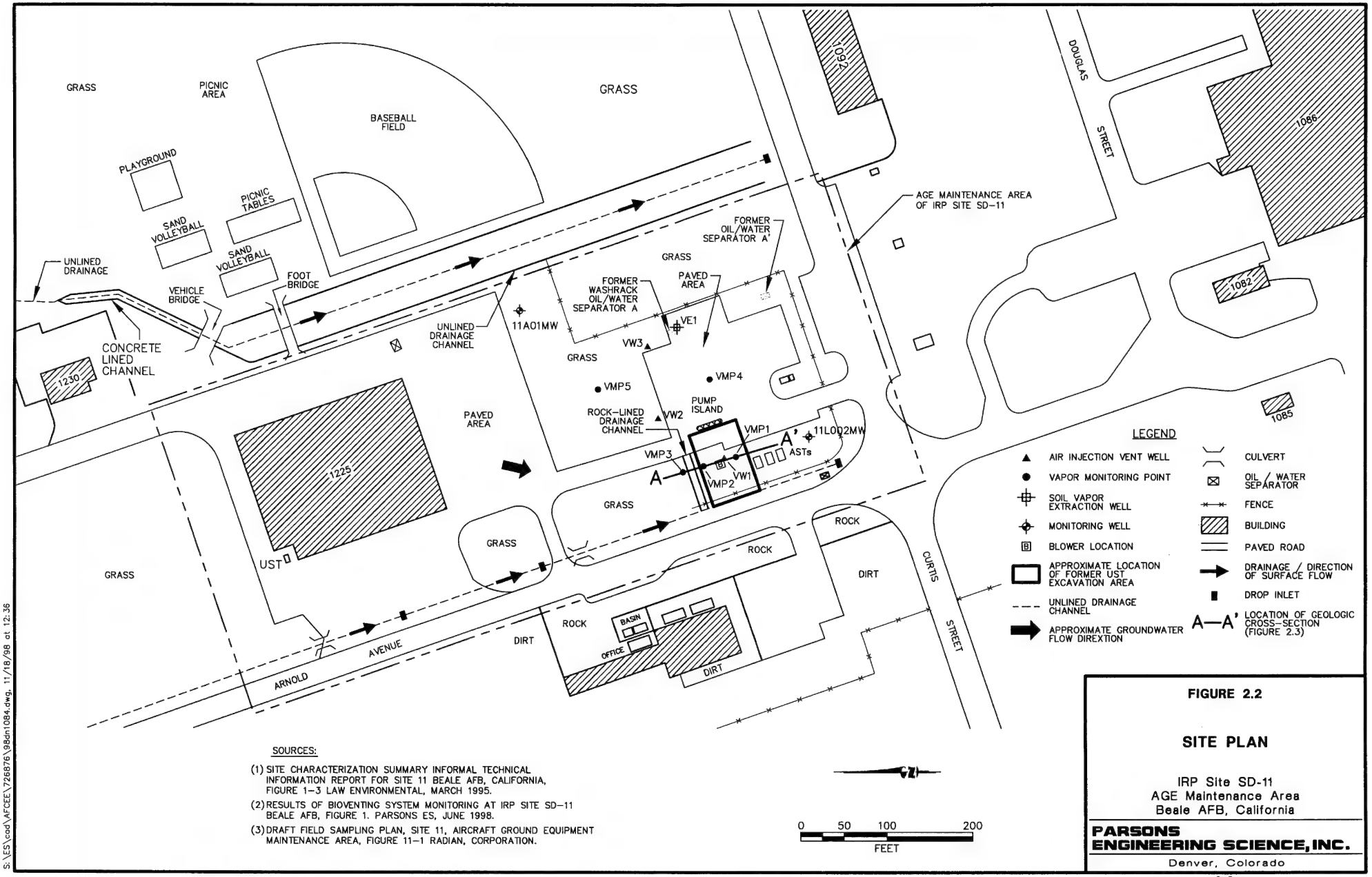
FIGURE 2.1

SITE LOCATION MAP

IRP Site SD-11
AGE Maintenance Area
Beale AFB, California

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado



SOURCES:

(1) SITE CHARACTERIZATION SUMMARY INFORMAL TECHNICAL INFORMATION REPORT FOR SITE 11 BEALE AFB, CALIFORNIA, FIGURE 1-3 LAW ENVIRONMENTAL, MARCH 1995.

(2) RESULTS OF BIOVENTING SYSTEM MONITORING AT IRP SITE SD-11 BEALE AFB, FIGURE 1. PARSONS ES, JUNE 1998.

(3) DRAFT FIELD SAMPLING PLAN, SITE 11, AIRCRAFT GROUND EQUIPMENT MAINTENANCE AREA, FIGURE 11-1 RADIAN, CORPORATION.

FIGURE 2.2

SITE PLAN

IRP Site SD-11
AGE Maintenance Area
Beale AFB, California

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

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2.2 SITE GEOLOGY AND HYDROGEOLOGY

The uppermost geologic unit in the western portion of Beale AFB, including IRP Site SD-11, has been mapped as the Laguna Formation. This formation consists of Plio-Pleistocene alluvial sequence of silt, sand, clay, and unsorted gravels. Sediments encountered during drilling completed during the fall of 1994 indicated a generalized sequence of interbedded silty sands and sandy gravels (Law Environmental, Inc., 1995).

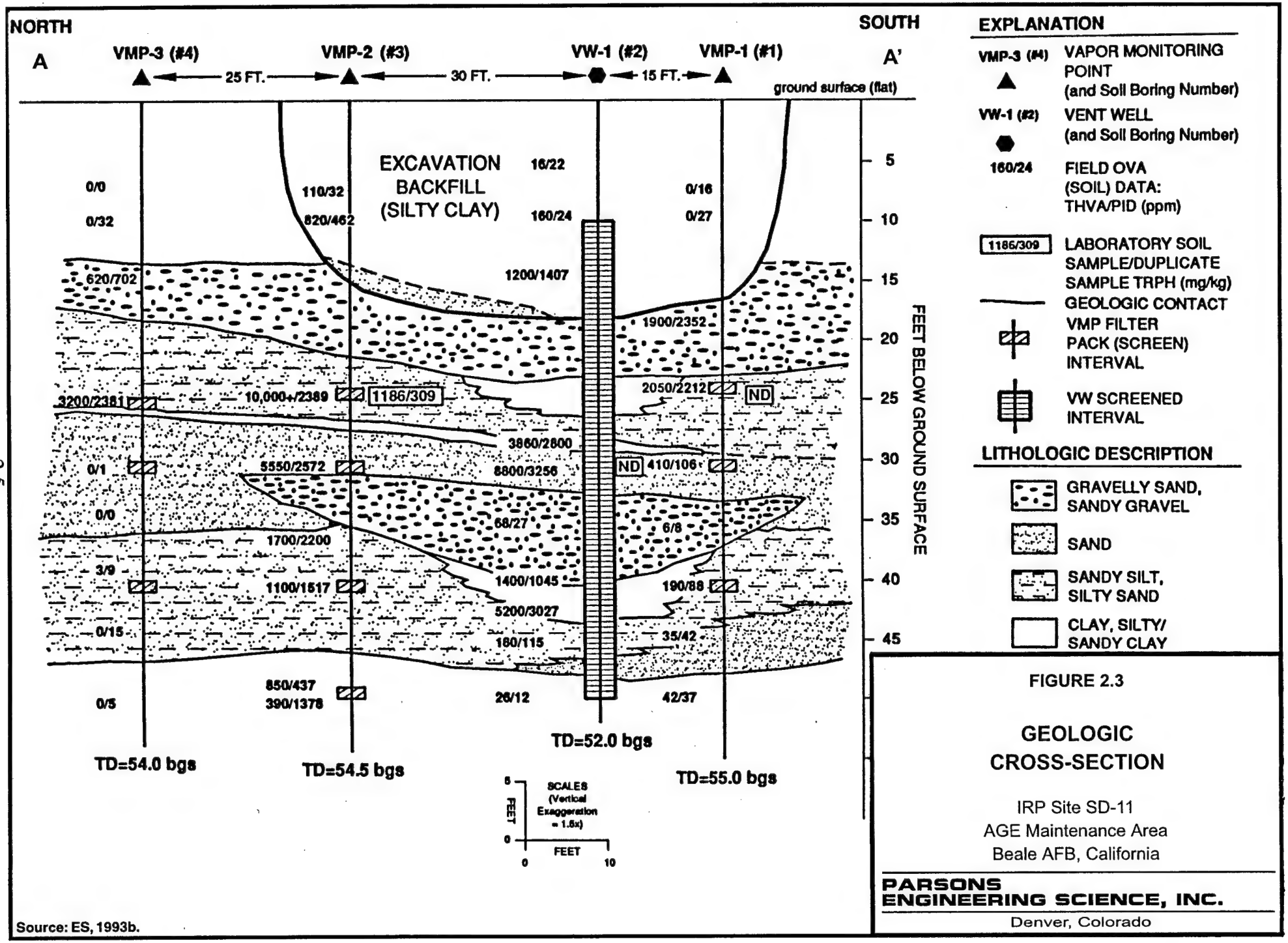
Sampling conducted by Parsons ES (formerly Engineering-Science, Inc. [ES]) during installation of the bioventing pilot test system indicated layers of gravelly sand, silts, and clays (ES, 1993b). The backfill materials for the former excavation are composed of silty clay with common gravel-sized fragments up to 2 inches in diameter. The base of this backfill material was found at depths between 15 and 20 feet below ground surface (bgs). A geologic cross-section based on this sampling event is provided at Figure 2.3.

Groundwater at the site is present at approximately 85 feet bgs (Radian Corporation, 1998). The first groundwater flow zone is generally unconfined and is expected to flow in a south-southwesterly direction (LCC, 1998).

2.3 PREVIOUS INVESTIGATIONS AND REMEDIATION ACTIVITIES

A chronological summary of the investigative and removal/remediation activities that have been performed at the site since June 1992 includes the following:

- June 1992 - Removal of the three former USTs;
- April 1993 - Installation of the bioventing pilot test system in the area of the former USTs by Parsons ES, 1993b);
- May 1993 to June 1994 - Performance of a 1-year extended bioventing pilot test and 1-year soil sampling by Parsons ES (AFCEE, 1995);
- Fall 1994 - Further site characterization of the AGE Maintenance Area by Law Environmental (1995);
- May 1996 to August 1996 - Expansion and optimization of the bioventing system to treat petroleum contaminated soils east of the UST excavation by Parsons ES (1995, 1996a, and 1996b);
- January 1997 - Removal of two oil/water separators on the east side of the AGE Maintenance Area by LCC (1998);
- June/July 1997 - Installation of a soil vapor extraction (SVE) system near Oil/Water Separator A by LCC (1998);
- 1997 - Monitoring and maintenance of the expanded bioventing system by Law Environmental (1997);



Source: ES, 1993b.

FIGURE 2.3

GEOLOGIC CROSS-SECTION

IRP Site SD-11
AGE Maintenance Area
Beale AFB, California

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

- April 1998 - Expanded bioventing system soil vapor sampling and respiration testing by Parsons ES (1998); and

- April/May 1998 - Reconfiguration of the bioventing system into a SVE system by LCC (1998).

2.3.1 Removal of USTs

During soil excavation and UST removal operations in June 1992, soil contamination was observed in soil beneath all three USTs (Tank Nos. 1225.01, 1225.02, and 1225.03). Although soil around and beneath the tanks was removed, some contaminated soil was left in place. The maximum depth of the soil excavation was reported at 30 feet bgs; however, the base of the fill material has been observed to be between 15 and 20 feet bgs (ES, 1993b).

During UST removal, 13 soil samples were collected from the excavation pit and analyzed for extractable petroleum hydrocarbons (total petroleum hydrocarbons [TPH] as diesel [TPH-d]) by USEPA Method SW3550/SW8015, purgeable petroleum hydrocarbons (TPH as gasoline [TPH-g]) by USEPA Method SW5030/SW8015, and purgeable aromatics (benzene, toluene, ethylbenzene, and total xylenes [BTEX]) by USEPA Method SW8020. During this sampling event, TPH-d and TPH-g were detected at maximum concentrations of 6,000 milligrams per kilogram (mg/kg) and 860 mg/kg, respectively (ES, 1993b). Benzene, toluene, ethylbenzene, and total xylenes were detected at maximum concentrations of 48 mg/kg, 190 mg/kg, 83 mg/kg, and 400 mg/kg, respectively.

2.3.2 Bioventing Pilot Test System Installation and Operation

In order to address the petroleum hydrocarbon contamination remaining in site soils following UST removal, Parsons ES installed a bioventing pilot test system at IRP Site SD-11 in April 1993 as part of the AFCEE Bioventing Initiative program (ES, 1993b). The purpose of this project was to determine if *in situ* bioventing would be a feasible cleanup technology for remediating the remaining fuel-contaminated unsaturated zone soils near the former UST excavation. The installed pilot-scale bioventing system consisted of one vent well (VW1), three multi-depth vapor monitoring points (VMP1, VMP2, and VMP3), a regenerative blower and blower housing, air supply piping, and electrical service (Figure 2.2).

The VW and VMPs were installed in accordance with procedures described in the protocol document (Hinchee *et al.*, 1992). The VW was screened from 10 to 50 feet bgs based on field evidence of petroleum contamination between 23 and 26 and 38 and 43 feet bgs. Three casing strings and 6-inch screens were installed in each VMP borehole at depths of approximately 24, 30, and 40 feet bgs to provide monitoring points at variable depths, soil types, and contamination levels. An additional casing string/screen was placed approximately 50 feet bgs at VMP2 because of high organic vapor analysis (OVA) readings and the presence of a clay layer at this depth interval (Figure 2.3). During system startup, the effective radius of oxygen influence was determined to be at least 55 feet for VW1 (ES, 1993b). Results of soil and soil vapor

samples collected prior to, during, and following the 1-year pilot test are presented in Tables 2.1 and 2.2, respectively.

The 1-year bioventing pilot test, completed in June 1994, demonstrated that bioventing is an effective treatment technology for petroleum-contaminated soils present within the unsaturated zone at the AGE Maintenance Area. The 1-year monitoring results also indicated that the long-term radius of oxygen influence may be as high as 70 feet from VW1. Total volatile hydrocarbon (TVH) and BTEX concentrations in soil vapor were reduced by as much as 4 orders of magnitude (Table 2.2). While similar reductions were not observed in three confirmatory soil samples collected in July 1994 (Table 2.1), this is likely due to a heterogeneous distribution of contamination and the inherent variability of limited soil sampling (Parsons ES, 1995). Based on the favorable pilot testing results, IRP Site SD-11 was included in the AFCEE Extended Bioventing Project for system expansion (Option 4) and 1 year of system operation and monitoring followed by soil vapor sampling and *in situ* respiration testing (Option 1). In anticipation of favorable expanded bioventing system results, the AFCEE Extended Bioventing Project also provided funding for confirmatory soil sampling and site closure (Option 2), if appropriate.

2.3.3 1994 Site Characterization

In the fall of 1994, Law Environmental performed a site characterization at IRP Site SD-11 which included collection of soil vapor samples, surface and subsurface soil samples, and groundwater samples (Law Environmental, 1995).

Soil vapor samples were collected from depths of 3 to 10 feet bgs to ascertain potential contaminant source areas and determine appropriate locations for subsequent soil sampling. Soil vapor samples were analyzed onsite for TPH, BTEX, and HVOCs using a mobile laboratory. Soil vapor sample results for the UST excavation area and adjoining areas are shown in Table 2.3. Soil vapor sample locations are shown on Figure 2.4. During this survey, TPH concentrations exceeding 13,000 parts per million, by volume (ppmv) and total BTEX results exceeding 70 ppmv were detected in four soil vapor samples (11L009VP, 11L021VP, 11L023VP, and 11L024VP) collected east of the UST excavation and pump island. The maximum TPH concentration (190,500 ppmv) and maximum total BTEX concentration (435 ppmv) were detected in the sample collected at 11L009VP, directly north of the concrete paved area, approximately 60 feet from the pump island. Trichloroethene (TCE) (0.11 ppmv), 1,2-dichloroethene (1,2-DCE) (0.42 ppmv), 1,1-DCE (0.50 ppmv), 1,2-dichloroethane (1,2-DCA) (5.8 ppmv), and methylene chloride (0.75 ppmv) also were detected at this location. The highest soil vapor concentrations of TCE (2.81 ppmv) and 1,2-DCE (31 ppmv) were detected in the sample collected at 11L008VP near former Oil/Water Separator A (Figure 2.4).

Following evaluation of the soil vapor sample results, Law Environmental advanced seven soil borings (11L002SB, 11L005SB, 11L008SB, 11L009SB, 11L0010SB, 11L0011SB, and 11L0012SB) and collected four surface soil samples (11L005SS, 11L007SS, 11L008SS, and 11L009SS) near the UST excavation (Figure 2.4). Soil sample results are shown in Table 2.4. TPH contamination exceeding 350 mg/kg was discovered in samples collected at 10, 15, and 62.5 feet bgs from soil boring 11L002SB located on the north side of the former UST excavation. Comparatively

TABLE 2.1
SUMMARY OF PARSONS ES SOIL ANALYTICAL SAMPLING RESULTS
IRP SITE SD-11
BEALE AFB, CALIFORNIA

Analyte[a/]	Units[b/]	Method	Sample Location - Depth (feet below ground surface)		
1993 Pilot-Scale Bioventing System Installation			VW1-30	VMP1-24.5	VMP2-25.5
TRPH	mg/kg	418.1	<5 [c/]	<5	1,186/309 [d/]
Benzene	mg/kg	SW5030/SW8020	0.0035	1.8	<4.0/<3.9
Toluene	mg/kg	SW5030/SW8020	0.020	1.8	150/48
Ethylbenzene	mg/kg	SW5030/SW8020	0.0043	0.11	68/27
Total Xylenes	mg/kg	SW5030/SW8020	0.039	0.65	510/129
1994 Pilot-Scale Bioventing 1-Year Results			VW1-30	VMP1-24.5	VMP2-25.5
TRPH	mg/kg	418.1	85.8	1,010	3,680
Benzene	mg/kg	SW5030/SW8020	0.0005	<0.61	<3.0
Toluene	mg/kg	SW5030/SW8020	0.013	<0.61	<3.0
Ethylbenzene	mg/kg	SW5030/SW8020	0.0076	<0.61	13
Total Xylenes	mg/kg	SW5030/SW8020	0.074	10	720
1996 Expanded Bioventing System Installation Results					
Total Hydrocarbons			VW2-10	VW2-50.5	VW3-24
TPH-g	mg/kg	SW5030/SW8015m	2,500	<1.2	<1.1
TPH-JP5	mg/kg	SW3550/SW8015m	160 Y[e/]L[f/]	<1.2	7 YH[g/]
TPH-d	mg/kg	SW3550/SW8015m	60 YLH	<1.2	18 YH
TPH-mo	mg/kg	SW3550/SW8015m	9.1 YL	<5.8	60 YH
Benzene	mg/kg	SW5030/SW8020	6.8	<0.0058	<0.0057
Toluene	mg/kg	SW5030/SW8020	94	<0.0058	<0.0057
Ethylbenzene	mg/kg	SW5030/SW8020	37	<0.0058	<0.0057
Total Xylenes	mg/kg	SW5030/SW8020	173	<0.0058	<0.0057

VMP4-13	VMP5-18.5
3.5 Y	<1.2
<1.2	90 YH
<1.2	300 YH
<6	290 YL
<0.006	<0.0062
<0.006	<0.0062
<0.006	<0.0062
<0.006	<0.0062

TABLE 2.1 (Continued)
SUMMARY OF PARSONS ES SOIL ANALYTICAL SAMPLING RESULTS
IRP SITE SD-11
BEALE AFB, CALIFORNIA

Analyte[a/]	Units[b/]	Method	Sample Location - Depth (feet below ground surface)				
1996 Expanded Bioventing System Installation Results (continued)							
Total Halogenated VOCs			VW2-10	VW2-50.5	VW3-24	VMP4-13	VMP5-18.5
HVOCs	mg/kg	SW5030/SW8010	all ND [h/]	all ND	all ND	all ND	all ND
Soluble Hydrocarbons							
TPH-JP5	ug/L	DI-WET[i/]/SW8015m	1,900 YLZ[j/]	-- [k/]	<50	--	<50
TPH-d	ug/L	DI-WET/SW8015m	610 YLZ	--	<50	--	<50
TPH-mo	ug/L	DI-WET/SW8015m	<300	--	<300	--	<300
Benzene	ug/L	DI-WET/SW8020	87	--	--	--	--
Toluene	ug/L	DI-WET/SW8020	950	--	--	--	--
Ethylbenzene	ug/L	DI-WET/SW8020	260	--	--	--	--
Total Xylenes	ug/L	DI-WET/SW8020	1,950	--	--	--	--

[a/] TRPH = total recoverable petroleum hydrocarbons; TPH-g = total petroleum hydrocarbons (TPH) as gasoline; TPH-JP5 = TPH as jet fuel #5 (C10-C16); TPH-d = TPH as diesel (C12-C22); and TPH-mo = TPH as motor oil (C22-C50).

[b/] mg/kg = milligrams per kilogram; µg/L = micrograms per liter.

[c/] < and gray shading = Compound analyzed for, but not detected. Number shown represents the labortory reporting limt.

[d/] Results of primary sample/field duplicate.

[e/] Y = sample exhibits fuel pattern which does not resemble standard.

[f/] L = lighter hydrocarbons than indicated in standard.

[g/] H = heavier hydrocarbons than indicated in standard.

[h/] all ND = halogenated VOCs were not detected.

[i/] DI-WET = deionized water extraction, waste extraction test.

[j/] Z = sample exhibits unknown single peak or peaks.

[k/] -- = not analyzed.

TABLE 2.2
SUMMARY OF PARSONS ES FIELD AND TVH AND BTEX SOIL ANALYTICAL VAPOR RESULTS
IRP SITE SD-11
BEALE AFB, CALIFORNIA

Sample Location	Depth (feet bgs)[a]	Sampling Event[b] (Date)	Field-Screening Data: Oxygen (percent)	Field-Screening Data: Carbon Dioxide (percent)	Field-Screening Data: TVH[c] (ppmv)[d]	Laboratory Data[e]: TVH[f] (ppmv)	Benzene (ppmv)	Toluene (ppmv)	Ethylbenzene (ppmv)	Xylenes (ppmv)	Total BTEX (ppmv)
PILOT-SCALE BIOVENTING SYSTEM COMPONENTS											
VW1	10-50	Initial (5/93)	2.0	8.0	9,600	51,000	30	74	13	310	427
		1-Year (7/94)	20.5	0.6	96	7.4	0.008	<0.002[g]	0.006	0.12	0.134
		3-Year (7/96)	19.9	0.3	12	--[h]	--	--	--	--	--
		5-Year (4/98)	19.7	0.7	0	6.5	<0.023	<0.023	<0.023	0.051	0.051
VMP1	24	Initial (5/93)	3.0	11.0	>10,000[i]	72,000	430	550	40	240	1,260
		1-Year (7/94)	10.0	3.2	1,200	3,500	1.2	12	10	140	163.2
		3-Year (7/96)	7.5	3.3	105	--	--	--	--	--	--
		5-Year (4/98)	6.0	3.9	100	37	<0.012	0.022	0.044	0.25	0.346
	30	Initial (5/93)	2.8	7.5	>10,000	--	--	--	--	--	--
		1-Year (7/94)	19.0	0.7	66	--	--	--	--	--	--
		3-Year (7/96)	20.0	0.5	10	--	--	--	--	--	--
		5-Year (4/98)	20.0	0.7	25	--	--	--	--	--	--
	40	Initial (5/93)	3.0	7.0	>10,000	--	--	--	--	--	--
		1-Year (7/94)	18.5	0.6	36	--	--	--	--	--	--
		3-Year (7/96)	19.0	0.5	10	--	--	--	--	--	--
		5-Year (4/98)	19.0	0.9	30	--	--	--	--	--	--
VMP2	24	Initial (5/93)	2.0	6.8	>10,000	--	--	--	--	--	--
		1-Year (7/94)	9.5	3.0	4,400	--	--	--	--	--	--
		3-Year (7/96)	9.5	3.5	260	--	--	--	--	--	--
		5-Year (4/98)	6.5	6.0	100	37	<0.024	0.037	0.041	0.23	0.308
	30	Initial (5/93)	3.5	7.2	>10,000	--	--	--	--	--	--
		1-Year (7/94)	19.0	0.6	300	--	--	--	--	--	--
		3-Year (7/96)	19.0	0.3	28	--	--	--	--	--	--
		5-Year (4/98)	20.4	0.6	10	--	--	--	--	--	--
	40	Initial (5/93)	3.0	6.6	>10,000	--	--	--	--	--	--
		1-Year (7/94)	17.8	0.8	780	--	--	--	--	--	--
		3-Year (7/96)	19.5	0.8	70	--	--	--	--	--	--
		5-Year (4/98)	19.9	0.7	20	--	--	--	--	--	--
	50	Initial (5/93)	2.2	6.2	7,800	--	--	--	--	--	--
		1-Year (7/94)	14.9	2.9	1,900	--	--	--	--	--	--
		3-Year (7/96)	17.5	2.0	110	--	--	--	--	--	--
		5-Year (4/98)	18.3	1.9	70	--	--	--	--	--	--

TABLE 2.2 (Continued)
SUMMARY OF PARSONS ES FIELD AND TVH AND BTEX SOIL ANALYTICAL VAPOR RESULTS
IRP SITE SD-11
BEALE AFB, CALIFORNIA

			Field-Screening Data			Laboratory Data[e/]					
Sample Location	Depth (feet bgs)[a/]	Sampling Event[b/] (Date)	Oxygen (percent)	Carbon Dioxide (percent)	TVH[c/] (ppmv)[d/]	TVH[f/] (ppmv)	Benzene (ppmv)	Toluene (ppmv)	Ethylbenzene (ppmv)	Xylenes (ppmv)	Total BTEX (ppmv)
VMP3	24	Initial (5/93)	1.0	6.6	2,000	55,000	580	970	59	350	1,959
		1-Year (7/94)	11.8	3.4	2,100	4,900	2.7	26	12	390	430.7
		3-Year (7/96)	12.0	3.0	1,100	4,200	<1.5	<1.5	<1.5	150	150
		3.1-Year (8/96)[j/]	17.5	2.0	1,000	3,600	0.89	<0.67	<0.67	62	62.89
		5-Year (4/98)	14.1	3.7	550	1,300	<0.12	0.17	0.63	14	14.8
	30	Initial (5/93)	1.5	7.8	9,200	--	--	--	--	--	--
		1-Year (7/94)	18.0	0.7	500	--	--	--	--	--	--
		3-Year (7/96)	18.5	0.5	53	--	--	--	--	--	--
		5-Year (4/98)	20.4	0.6	5	--	--	--	--	--	--
	40	Initial (5/93)	1.6	5.8	5,600	--	--	--	--	--	--
		1-Year (7/94)	18.2	0.6	100	--	--	--	--	--	--
		3-Year (7/96)	18.5	0.3	16	--	--	--	--	--	--
		5-Year (4/98)	20.4	0.6	10	--	--	--	--	--	--
EXPANDED BIOVENTING SYSTEM COMPONENTS											
VW2	10-40	Initial (7/96)	20.5	0.3	200	52/28[k/]	0.28/0.069	0.26/0.055	<0.037/<0.036	0.88/0.79	1.42/0.914
		1.75-Year (4/98)	20.4	0.6	0	--	--	--	--	--	--
VW3	10-40	Initial (7/96)	20.8	0.0	2	5.3	0.0058	0.0021	<0.00073	0.0101	0.018
		1.75-Year (4/98)	20.8	0.5	0	--	--	--	--	--	--
VMP4	10	Initial (7/96)	18.0	1.9	190	99/150	0.048/0.100	<0.021/<0.00	<0.021/<0.009	0.021/<0.00	0.048/0.100
		1-month (8/96)[j/]	16.5	2.8	1,000	1,200	0.23	<0.049	<0.049	<0.049	0.23
		1.75-Year (4/98)	3.7	9.2	9000[j/]	<9.9/<12.0	<0.99/<1.2	<0.99/<1.2	<0.99/<1.2	<0.99/<1.2	<3.96/<4.8
	24	Initial (7/96)	19.5	0.8	46	--	--	--	--	--	--
		1.75-Year (4/98)	19.0	1.0	50	<0.0081	<0.00081	<0.00081	<0.00081	0.0051	--
	30	Initial (7/96)	20.8	0.0	290	<0.360	<0.360	<0.360	<0.360	<0.360	<1.44
		1-month (8/96)[j/]	20.6	0.3	14	0.66	<0.0012	<0.0012	<0.0012	<0.0012	<0.0048
		1.75-Year (4/98)	20.8	0.5	0	--	--	--	--	--	--
	40	Initial (7/96)	20.8	0.3	66	--	--	--	--	--	--
		1.75-Year (4/98)	20.8	0.5	0	--	--	--	--	--	--

TABLE 2.2 (Continued)
SUMMARY OF PARSONS ES FIELD AND TVH AND BTEX SOIL ANALYTICAL VAPOR RESULTS
IRP SITE SD-11
BEALE AFB, CALIFORNIA

			Field-Screening Data			Laboratory Data[e/]					
Sample Location	Depth (feet bgs)[a/]	Sampling Event[b/] (Date)	Oxygen (percent)	Carbon Dioxide (percent)	TVH[c/] (ppmv)[d/]	TVH[f/] (ppmv)	Benzene (ppmv)	Toluene (ppmv)	Ethylbenzene (ppmv)	Xylenes (ppmv)	Total BTEX (ppmv)
VMP5	10	Initial (7/96)	11.9	4.5	74	1.8	0.0038	0.0012	<0.00078	<0.00078	0.005
		1-month (8/96)[j/]	16.8	>5.0	100	0.072	<0.00070	0.00078	<0.00070	<0.00070	0.00078
		1.75-Year (4/98)	20.6	0.8	16	--	--	--	--	--	--
	24	Initial (7/96)	20.8	0.3	100	--	--	--	--	--	--
		1.75-Year (4/98)	20.8	0.5	0	--	--	--	--	--	--
	30	Initial (7/96)	20.8	0.3	94	--	--	--	--	--	--
		1.75-Year (4/98)	20.8	0.5	0	--	--	--	--	--	--
	40	Initial (7/96)	20.8	0.3	16	--	--	--	--	--	--
		1.75-Year (4/98)	20.8	0.5	0	--	--	--	--	--	--

[a/] ft bgs = feet below ground surface.
[b/] Sampling events identified based upon approximate time since pilot-scale and expanded-scale bioventing began in May 1993 and July 1996, respectively.
[c/] TVH = total volatile hydrocarbons.
[d/] ppmv = parts per million, by volume.
[e/] Laboratory analysis of soil vapor performed using either USEPA Method TO-3 or USEPA Method TO-14.
[f/] TVH referenced to jet fuel and gasoline when analyzed by Method TO-3 and Method TO-14, respectively.
[g/] < and gray shading = Compound analyzed for, but not detected. Number shown represents the laboratory reporting limit.
[h/] -- = not analyzed.
[i/] > = concentration greater than maximum reading on field instrument.
[j/] System operating during sampling event; results represent "dynamic" conditions 1 month following expanded bioventing system startup.
[k/] Original sample result/duplicate result.
[l/] Although TVH and BTEX were not detected in the analytical sample, 4,900 ppmv of non-methane organic hydrocarbons (referenced to heptane) were detected by the laboratory.

TABLE 2.3
SUMMARY OF 1994 LAW ENVIRONMENTAL SOIL VAPOR ANALYTICAL RESULTS IN THE UST EXCAVATION AREA AND ADJOINING AREAS
IRP SITE SD-11
BEALE AFB, CALIFORNIA

Sample Location	Sample Date	Depth (ft bgs)[c/]	Petroleum Hydrocarbons[a/]						HVOCs[b/]						
			TPH	Benzene	Toluene	Ethyl-benzene	Total Xylenes	Total BTEX	TCE	PCE	1,2-DCE	1,1-DCE	1,2-DCA	1,1,1-TCA	Methylene Chloride
			results in ppmv[d/]						results in ppmv						
11L008VP	8/15/94	7.0	1,572	10.15	3.46	0.39	1.52	15.52	2.81	ND[e/]	31.0	0.27	ND	ND	ND
11L009VP	8/16/94	10.0	190,500	242.44	170.05	4.84	17.83	435.16	0.11	ND	0.42	0.50	5.8	ND	0.75
11L010VP	8/16/94	8.0	1,860	6.3	2.45	0.14	0.64	9.53	0.02	0.01	0.09	ND	0.05	0.02	ND
11L011VP	8/16/94	7.5	21	8.55	5.02	0.12	0.56	14.25	0.04	ND	0.10	ND	0.09	ND	ND
11L012VP	8/16/94	10.0	12	0.22	0.22	ND	0.13	0.57	ND	ND	ND	ND	ND	ND	ND
11L013VP	8/16/94	10.0	11	0.17	0.24	0.02	0.15	0.58	ND	ND	ND	ND	ND	ND	ND
11L014VP	8/16/94	10.0	3,047	28.08	18.88	4.51	17.16	68.63	0.04	ND	0.12	ND	0.16	ND	ND
11L015VP	8/16/94	10.0	317	4.54	4.49	0.75	4.65	14.43	ND	ND	ND	ND	0.02	ND	0.03
11L016VP	8/16/94	10.0	14	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
11L017VP	8/16/94	10.0	3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
11L018VP	8/16/94	10.0	7	0.03	0.14	0.08	0.73	0.98	ND	ND	ND	ND	ND	ND	ND
11L019VP	8/16/94	10.0	37	0.1	0.29	0.63	5.41	6.43	ND	ND	ND	ND	ND	ND	ND
11L020VP	8/16/94	10.0	5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
11L021VP	8/16/94	4.5	13,040	70.58	1.57	ND	0.25	72.40	ND	ND	ND	ND	ND	ND	ND
11L022VP	8/16/94	5.0	873	6.56	0.61	0.91	3.72	11.8	ND	ND	ND	ND	ND	ND	ND
11L023VP	8/16/94	9.0	37,700	114.72	80.12	4.78	19.02	218.64	0.23	ND	ND	ND	ND	ND	ND
11L024VP	8/17/94	8.0	106,000	259.65	87.14	ND	6.41	353.2	0.02	ND	ND	ND	0.71	ND	0.15
11L025VP	8/17/94	10.0	2	0.07	0.13	0.05	0.11	0.36	ND	ND	ND	ND	ND	ND	ND
11L026VP	8/17/94	3.0	22	0.23	0.35	0.03	0.18	0.79	ND	ND	0.03	ND	ND	ND	ND
11L037VP	9/14/94	7.5	345	3.77	1.45	0.27	0.44	5.93	ND	ND	ND	ND	ND	ND	ND

Source: Law, 1995.

[a/] Total petroleum hydrocarbon and BTEX analysis by USEPA Methods SW8015 and SW8020, respectively.

[b/] HVOCs = halogenated volatile organic compounds analyzed by USEPA Method SW8010. TCE = trichloroethene; PCE = tetrachloroethene (or perchloroethene); DCE = dichloroethene. DCA = dichloroethane, and TCA = trichloroethane.

[c/] ft bgs = feet below ground surface.

[d/] ppmv = parts per million, by volume.

[e/] ND and gray shading = analyte not detected.

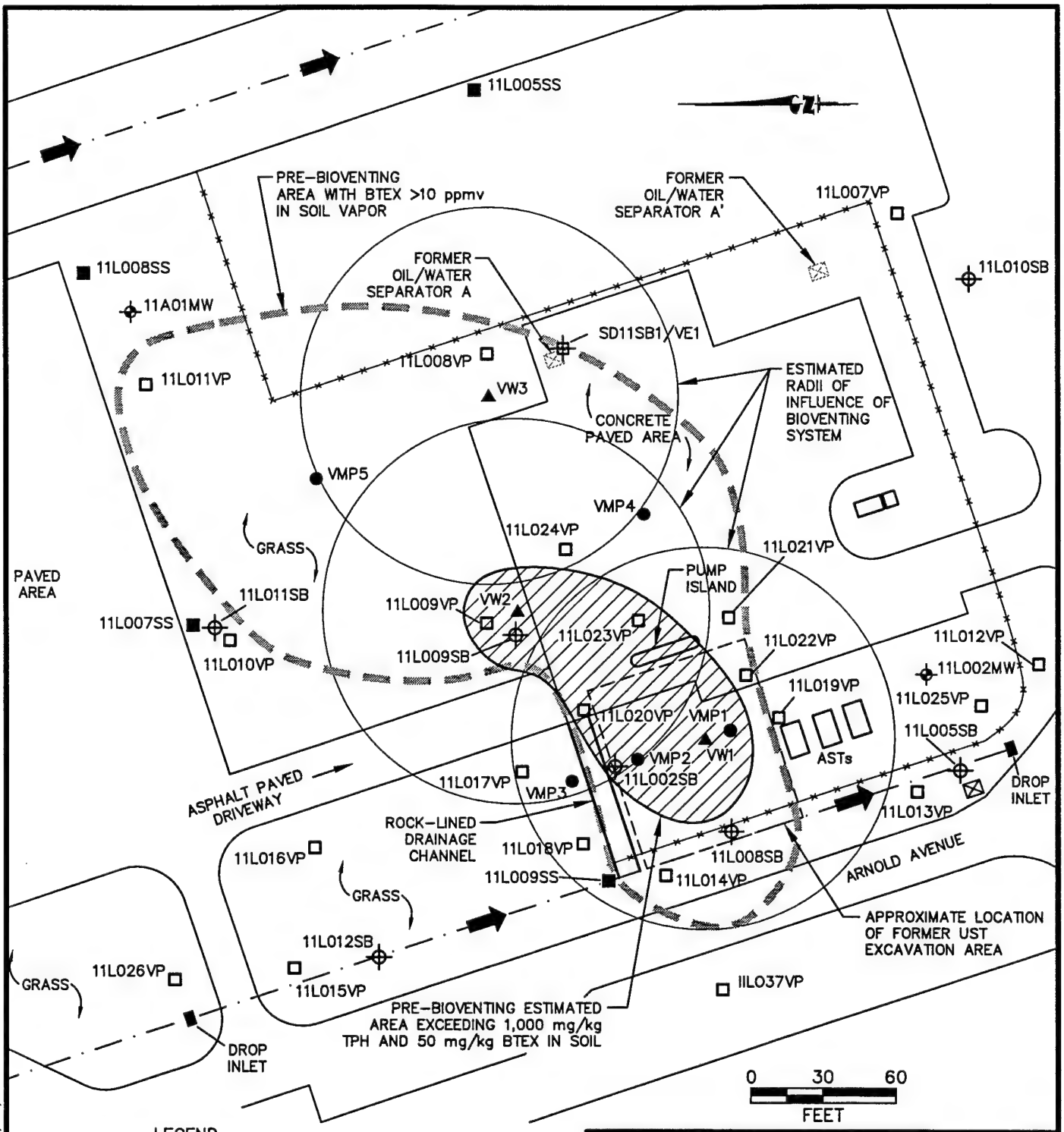


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FIGURE 2.4

SITE MAP AND PREVIOUS SAMPLING LOCATIONS IN THE UST EXCAVATION AREA AND ADJOINING AREAS

IRP Site SD-11
AGE Maintenance Area
Beale AFB, California

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

TABLE 2.4
SUMMARY OF 1994 LAW ENVIRONMENTAL SOIL ANALYTICAL RESULTS IN THE UST EXCAVATION AREA AND ADJOINING AREAS
IRP SITE SD-11
BEALE AFB, CALIFORNIA

		Total Petroleum Hydrocarbons[a]					BTEX				HVOCs[b]			
		TPH-g	TPH-d	TPH-jf	TPH-ts	TRPH	Benzene	Toluene	Ethyl-benzene	Total Xylenes	1,2-DCA	2-Butanone	2-Hexanone	4-Methyl-2-Pentanone
Analytical Method :		SW8015M				418.1	SW8260 or SW8020				SW8260			
Sample Location	Depth (ft bgs)[c]	results in mg/kg[d]					results in mg/kg				results in mg/kg			
Soil Borings														
11L002SB	5.0	ND[e]	24	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
11L002SB	10.0	ND	2,000	2,900	ND	ND	ND	9 JH[f]	5 JH	39	ND	ND	ND	ND
11L002SB	15.0	610 J	ND	ND	350	ND	0.02	0.56	0.27	3.6	ND	ND	ND	ND
11L002SB	34.5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
11L002SB	39.5	ND	ND	ND	ND	ND	ND	ND	ND	0.001 J[g]	ND	ND	0.015 J	0.006 J
11L002SB	45.5	0.56 J	ND	ND	ND	ND	ND	ND	0.002	0.002	ND	ND	ND	0.007 J
11L002SB	46.5	0.64 J	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
11L002SB	47.5	1.0 J	6.0 J	ND	ND	ND	ND	ND	ND	ND	ND	0.016 JH	ND	ND
11L002SB	49.5	ND	ND	ND	ND	ND	ND	ND	ND	0.003	ND	ND	ND	ND
11L002SB	62.5	760 J	ND	ND	1,200	ND	ND	ND	1 JH	16 JH	ND	ND	ND	ND
11L005SB	94.0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
11L005SB	95.0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
11L008SB	75.0	ND	ND	ND	ND	ND	ND	ND	ND	0.001	ND	ND	ND	ND
11L008SB	100.0	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.003	0.002 R[h]	ND	ND
11L009SB	75.0	ND	20	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
11L009SB	105.5	ND	ND	ND	ND	ND	ND	0.06	0.004	0.4	ND	ND	ND	ND
11L010SB	102.0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
11L011SB	99.0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
11L012SB	89.0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Shallow Soil Samples														
11L005SS	0.7	ND	33	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
11L007SS	0.4	ND	72	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
11L008SS	0.2	ND	260	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
11L009SS	0.4	ND	390	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.005 J

Source: Law, 1995.

[a] TPH-g = total petroleum hydrocarbons (TPH) as gasoline; TPH-d = TPH as diesel; TPH-jf = TPH as jet fuel; TPH-ts = TPH as test grade jet fuel; and TRPH = total recoverable petroleum hydrocarbons.

[b] HVOCs = halogenated volatile organic compounds; 1,2-DCA = 1,2-dichloroethane.

[c] ft bgs = feet below ground surface.

[d] mg/kg = milligrams per kilogram.

[e] ND and gray shading = analyte not detected.

[f] JH = results are estimated; high bias indicated.

[g] J = results are estimated due to lack of precision.

[h] R = sample results are rejected as unusable.

limited contamination was evident in samples collected from 11L008SB on the west side of the UST excavation and from 11L009SB north of the concrete paved area. TPH and BTEX were not detected in soil samples collected from other soil borings located in areas adjoining the UST excavation area. For the surface soil samples, TPH-d was detected at 390 mg/kg in the sample collected on the north side of UST excavation and rock-lined drainage channel (11L009SS). TPH-d also was detected at 11L005SS (33 mg/kg), 11L007SS (72 mg/kg), and 11L008SS (260 mg/kg).

Petroleum hydrocarbons and HVOCs also were detected in groundwater samples collected from nearby monitoring wells in October and November 1994. At monitoring well 11A01MW, 1,1,2,2-tetrachloroethane was detected at 12 micrograms per liter (μg/L) and TCE was detected at 5 μg/L. At monitoring well 11L002MW, toluene, ethylbenzene, and total xylenes were detected at 22 μg/L, 3 μg/L, and 48 μg/L, respectively, which are below their respective Water Quality Goals (WQGs) identified by the California Environmental Protection Agency (Cal/EPA, 1998). In addition, 1,1,2,2-tetrachloroethane, chloroform, methylene chloride, and TCE were detected at 12 μg/L, 1μg/L, 1μg/L, and 4μg/L, respectively.

2.3.4 Bioventing System Expansion and Optimization

The expanded bioventing system was installed by Parsons ES between May 28 and July 8, 1996. The system was installed in accordance with the final work plan (Parsons ES, 1995) and design package (Parsons ES, 1996a). The expanded system included two additional air injection VWs (VW2 and VW3), two additional VMPs (VMP4 and VMP5), an upgraded 3-horsepower blower system and housing, and associated piping, controls, and electrical service (Figure 2.4). The expanded system VWs were screened from 10 to 40 feet bgs and the new VMPs were installed near the expected radius of influence of the VWs to evaluate vapor migration. Four casing strings and 6-inch screens were installed in each VMP boring at approximately 10, 24, 30, and 40 feet bgs. Soil and soil vapor samples were collected for field and laboratory analysis prior to system startup to establish baseline conditions for the expanded bioventing system (Tables 2.1 and 2.2).

In August 1996, following four weeks of air injection into VW2 and VW3, an additional set of soil vapor samples was collected during expanded bioventing system operation to evaluate potential vapor migration from the areas of the site undergoing air injection for the first time. Parsons ES did not reestablish air flow to VW1, but recommended returning air flow to VW1 at approximately 10 cubic feet per minute (cfm) based on the low vapor migration indicated during the August 1996 sampling event (Parsons ES, 1996b).

2.3.5 Removal of Oil/Water Separators and Vapor Extraction Well Installation

In January 1997, LCC removed Oil/Water Separator A and Oil/Water Separator A' located on the eastern side of the AGE Maintenance Area. Following removal, six soil samples were collected from soils directly beneath and adjacent to the former oil/water separators. Samples were analyzed for TPH-g by USEPA Method SW8015, volatile organic compounds (VOCs) by USEPA Method SW8260, soluble TPH-d using a deionized water-waste extraction test (DI-WET) preparation, and total metals by

USEPA Method SW6010. Maximum concentrations of 2.9 milligrams per liter (mg/L) of soluble TPH-d and 4.3 mg/kg of TCE were detected in soils impacted by former Oil/Water Separator A northeast of the concrete paved area. All other target analyte concentrations were below established action levels (LCC, 1998).

In June 1997, LCC further investigated soil and soil vapor contamination beneath Oil/Water Separator A. One soil boring was advanced at this location from ground surface to 87 feet bgs. Eleven soil vapor samples were collected between 5 and 87 feet bgs to determine the vertical extent of contamination. Soil vapor samples were analyzed for VOCs by USEPA Method SW8010/8020 using an onsite mobile laboratory. No BTEX constituents were detected above the 0.05 ppmv reporting limit. Soil vapor concentrations exceeding 200 ppmv of TCE, *cis*-1,2-DCE, *trans*-1,2-DCE, and 1,1-DCE were detected in the soil vapor sample collected from 10 to 11 feet bgs. Concentrations of VOCs above established cleanup levels were not identified in soil vapor samples collected at depths greater than 45 feet bgs. Based on the results of this investigation and the previous Law Environmental (1995) investigation, LCC (1998) estimated that the HVOC contamination was limited to the upper 45 feet of the vadose zone within a radius of approximately 100 feet from Oil/Water Separator A.

Following soil boring advancement, a vapor extraction well (VE1) was installed at the former location of Oil/Water Separator A and SVE start up testing was performed. Vapor extraction well VE1 was screened from 10 to 50 feet bgs. The SVE start up testing consisted of applying a vacuum to VE1 and measuring the air flow rate at the well head and pressure differentials at the bioventing VMPs. During the testing, vacuums ranging from 0.36 to 1.9 inches of water (in H_2O) were measured at the VMPs. An effective radius of influence of 180 feet was estimated for VE1 (LCC, 1998).

2.3.6 Option 1 Testing of the Expanded Bioventing System

Option 1 soil vapor sampling and respiration testing was originally scheduled for August 1997 following 1 year of expanded bioventing system operation and 1-month of system shutdown. However, when Parsons ES contacted Beale AFB personnel to schedule the Option 1 field work, it was discovered that an "area" respiration test was performed at the site in late June 1997 by Law Environmental. During an "area" respiration test, the blower system is used to oxygenate site soils and is shut down immediately prior to testing. In contrast, during a "point" respiration test, equilibrium conditions are allowed to return to site soils before an ambient air pump is used to locally oxygenate site soils. Following blower or air pump shutdown, oxygen utilization by indigenous soil bacteria, as they aerobically biodegrade petroleum hydrocarbons in soil, is measured at the VMPs.

Parsons ES evaluated the results of the "area" respiration test performed by Law Environmental and determined a "point" respiration test following 1 month of system shutdown (similar to those performed initially and following 1-year of pilot-scale bioventing system operation) was more appropriate for the Option 1 test. System shutdown for 1 month prior to "point" testing is necessary to allow site soil and soil vapor to return to equilibrium conditions and allow comparison with previous site results. Blower shutdown and Option 1 field work were rescheduled for mid-February and mid-March 1998, respectively.

In March 1998, Parsons ES was informed by Beale AFB personnel that elevated concentrations of HVOCs were detected at the 10-foot bgs screened interval at VMP4 (VMP4-10) during the third quarter 1997 sampling event performed by Law Environmental (Figure 2.2). During this sampling event, 68 ppmv of *cis*-1,2-DCE, 15 ppmv of *trans*-1,2-DCE, and 11 ppmv of TCE were measured at VMP4-10 as compared to 0.063 ppmv, 0.0093 ppmv, and 0.016 ppmv, respectively, during the second quarter 1997 sampling event. A review of the O&M monitoring logs for the blower system indicates that the bypass valve which was used to bleed excess airflow to the atmosphere was inappropriately closed when air injection was reestablished for VW1 in April 1997 (following the second quarter 1997 sampling event) (Law Environmental, 1997).

Parsons ES visited the site during the week of 16 March 1998 to perform Option 1 testing, but unexpectedly discovered that the blower system was running (the blower was turned off in mid-February), and Option 1 testing could not be initiated. Airflow measurements confirmed that approximately 4 times the original flowrate of air was being injected into VW2 and VW3 as a result of previous adjustments made to the system. In addition, the air flow rate into VW1 was almost 2 times higher than airflow into VW2 and VW3, and significantly exceeded recommended airflow rates for extended system operation (Parsons ES, 1996b).

Following system measurements, Parsons ES shut down the blower system, locked out power to the blower and rescheduled field work for mid-April 1998. Parsons ES performed Option 1 soil vapor sampling and respiration testing during the week of 13 April 1998. Field soil vapor results and analytical soil vapor results for TVH and BTEX from this sampling event are shown in Table 2.2. Table 2.5 summarizes the July 1996, August 1996, and April 1998 HVOC and non-petroleum hydrocarbon VOC results obtained by Parsons ES at VMP4.

2.3.7 Bioventing System Reconfiguration for Soil Vapor Extraction

As a result of the increased HVOC concentrations at VMP4 and data obtained during the LCC investigation, the bioventing blower system at Site SD-11 was reconfigured for SVE by LCC and Metcalf and Eddy, Inc., and plumbed to VE1 near former Oil/Water Separator A. Start up of the SVE system began in May 1998 and system operation and maintenance is currently being performed by CH2M Hill (Gaudette, 1998).

2.4 BIOVENTING SYSTEM EFFECTIVENESS

The Option 1 letter results report (Parsons ES, 1998) provided a summary of the soil vapor chemistry results and *in situ* respiration testing following more than 3 years of pilot-scale bioventing system operation and 1 year and 9 months of expanded bioventing system operation. Soil vapor chemistry results from the April 1998 Option 1 testing event and previous sampling events performed by Parsons ES are summarized in Tables 2.2 and 2.5. Table 2.6 summarizes the respiration and fuel biodegradation rates determined during the Option 1 testing event and compares them to rates determined during pilot-scale bioventing.

TABLE 2.5
SUMMARY OF SOIL VAPOR VOC ANALYTICAL RESULTS AT VMP4
IRP SITE SD-11
BEALE AFB, CALIFORNIA

Analyte[a]	Units[b]	VMP-4-10					VMP-4-24	VMP-4-30	
		Jul-96	Dup[c](Jul-96)	Aug-96[d]	Apr-98	Dup (Apr-98)	Apr-98	Jul-96	Aug-96[d]
Halogenated VOCs									
PCE	(ppmv)	<0.021[e]	[<0.0090]	<0.049	<0.990	[<1.2]	<0.00081	<0.036	<0.0012
TCE	(ppmv)	0.32	[0.37]	1.2	10	[11]	0.0047	<0.036	<0.0012
cis-1,2-DCE	(ppmv)	1.2	[1.4]	2.6	57	[65]	0.024	<0.036	<0.0012
trans-1,2-DCE	(ppmv)	0.22	[0.30]	1.2	13	[15]	0.0054	<0.14	<0.0046
Vinyl Chloride	(ppmv)	0.078	[0.10]	<0.049	4.6	[5.4]	0.0016	<0.036	<0.0012
1,1,1-TCA	(ppmv)	<0.021	[<0.0090]	<0.049	<0.990	[<1.2]	<0.00081	0.037	<0.0012
1,1-DCE	(ppmv)	<0.021	[<0.0090]	0.069	<0.990	[<1.2]	<0.00081	<0.036	<0.0012
1,2-DCA	(ppmv)	<0.021	[<0.0090]	<0.049	<0.990	[<1.2]	<0.00081	<0.036	<0.0012
Chloroform	(ppmv)	<0.021	[<0.0090]	<0.049	<0.990	[<1.2]	<0.00081	<0.036	<0.0012
Methylene Chloride	(ppmv)	<0.021	[<0.0090]	<0.049	<0.990	[<1.2]	<0.00081	<0.036	<0.0012
Freon 12	(ppmv)	<0.021	[<0.0090]	<0.049	<0.990	[<1.2]	<0.00081	<0.036	<0.0012
Other VOCs									
1,3,5-TMB	(ppmv)	<0.021	[<0.0090]	0.049	<0.990	[<1.2]	0.015	<0.036	0.0016
1,2,4-TMB	(ppmv)	<0.021	[<0.0090]	0.078	<0.990	[<1.2]	0.0053	<0.036	0.0048
Propylene	(ppmv)	<0.082	[<0.036]	<0.190	<3.9	[<4.7]	0.029	<0.14	<0.0046
Acetone	(ppmv)	<0.082	[<0.036]	<0.190	<3.9	[<4.7]	0.0049	<0.14	<0.0046
Carbon Disulfide	(ppmv)	<0.082	[<0.036]	<0.190	<3.9	[<4.7]	<0.0032	<0.14	<0.0046
2-Propanol	(ppmv)	<0.082	[<0.036]	<0.190	<3.9	[<4.7]	<0.0032	<0.14	<0.0046
Hexane	(ppmv)	5.6	[7.0]	10	250	[280]	0.086	<0.14	<0.0046
Tetrahyrdrofuran	(ppmv)	<0.082	[<0.036]	<0.190	<3.9	[<4.7]	0.013	<0.14	<0.0046
Cyclohexane	(ppmv)	<0.082	[<0.036]	<0.190	440	[500]	0.160	<0.14	<0.0046
1,4-Dioxane	(ppmv)	<0.082	[<0.036]	<0.190	<3.9	[<4.7]	0.0034	<0.14	<0.0046
2-Hexanone	(ppmv)	<0.082	[<0.036]	<0.190	<3.9	[<4.7]	<0.0032	<0.14	<0.0046
4-Ethyltoluene	(ppmv)	<0.082	[<0.036]	<0.190	<3.9	[<4.7]	<0.0032	<0.14	<0.0046
Heptane	(ppmv)	<0.082	[<0.036]	3.7	65	[76]	0.025	<0.14	<0.0046

Note: TVH and BTEX analytical data provided in Table 2.2.

[a] PCE = tetrachloroethene (perchloroethene); TCE = trichloroethene; DCE = dichloroethene; TCA = trichloroethane; DCA = dichloroethane; TMB = trimethylbenzene. Laboratory analysis of soil vapor performed using USEPA Method TO-14.

[b] ppmv = parts per million, by volume.

[c] Dup = duplicate; results shown in brackets.

[d] System operating during sampling event; results represent "dynamic" conditions 1 month following expanded bioventing system startup.

[e] < and gray shading = Compound analyzed for, but not detected. Number shown represents the laboratory reporting limit.

TABLE 2.6
SUMMARY OF RESPIRATION AND FUEL BIODEGRADATION RATES
IRP SITE SD-11
BEALE AFB, CALIFORNIA

Location-Depth (feet below ground surface)	Initial (May 1993)		6-Month (December 1993)[b/]		1-Year (July 1994)		5-Year (April 1998)[b/c/]	
	Respiration Rate ($\%O_2$/hour)	Degradation Rate (mg/kg/year)[a/]	Respiration Rate ($\%O_2$/hour)	Degradation Rate (mg/kg/year)	Respiration Rate ($\%O_2$/hour)	Degradation Rate (mg/kg/year)	Respiration Rate ($\%O_2$/hour)	Degradation Rate (mg/kg/year)
VMP1-24	0.12	50	0.039	47	0.036	71	0.14	180
VMP2-24	0.047	130	0.038	110	0.023	63	0.034	100
VMP3-24	NS[d/]	NC[e/]	NS	NC	NS	NC	0.034	100
VMP3-30	0.18	530	0.016	47	0.039	110	NS	NC
VMP4-10	NA[f/]	NA	NA	NA	NA	NA	0.060	180

[a/] mg/kg/year = Milligrams of hydrocarbons per kilogram of soil per year.

[b/] Assumes moisture content of the soil is average of initial and 1-year moistures.

[c/] 5-year testing event represents approximate time since initial testing in May 1993, not necessarily the cumulative bioventing treatment time.

[d/] NS = not sampled.

[e/] NC = not calculated; degradation rates cannot be estimated without respiration rate data.

[f/] NA = not applicable; VMP4 installed in July 1996 as part of the expanded-scale bioventing system.

Soil vapor and *in situ* respiration testing results from the April 1998 sampling event revealed the following:

- Analytical soil vapor results for TVH and BTEX indicate that petroleum-hydrocarbon contamination remaining in soils surrounding VMP1-24, VMP2-24, and VMP4-10 is minimal (Table 2.2);

- Concentrations of petroleum hydrocarbons in soil vapor collected from VMP3-24 were further reduced during expanded bioventing system operation, but continue to be slightly elevated (1,300 ppmv of TVH and 14.8 ppmv of total BTEX, 14 ppmv of xylenes) (Table 2.2);

- Elevated concentrations of TCE, 1,2-DCE, vinyl chloride, hexane, heptane, and cyclohexane detected in soil vapor near VMP4-10 appear to be the result of excessive air injection flowrates attributable to improper blower system adjustments (Table 2.5);

- Average *in situ* respiration and fuel biodegradation rates 5 years after initiating bioventing activities are approximately half those initially observed (Table 2.6);

- Aerobic biodegradation of residual petroleum hydrocarbon contaminants in soil is still occurring, albeit at relatively low rates (Table 2.6);

- Low BTEX soil vapor concentrations (Table 2.2) coupled with "flat" respiration and fuel biodegradation rates (Table 2.6) suggest that the residual hydrocarbon contamination remaining in site soils is primarily composed of less mobile, more biologically recalcitrant, higher molecular weight hydrocarbons; and

- Except for samples collected at VMP4-10, VMP1-24, VMP2-24, and VMP3-24, static oxygen concentrations in soils treated by the bioventing system were at or near atmospheric levels (20.9 percent) (Table 2.2). Static oxygen concentrations above 5 percent throughout most of the site indicates that microbial oxygen demand is being met through natural air diffusion and engineered air injection may no longer be required.

2.5 SUMMARY OF REMAINING SITE CONTAMINANTS

The presence of HVOCs in site soil, soil vapor, and groundwater has been attributed to the former oil/water separators located on the eastern side of the AGE Maintenance Area. Elevated concentrations of HVOCs detected at VMP4-10 during April 1998 appear to have resulted from excessive air injection at VW3 and contaminated vapor migration from soils near former Oil/Water Separator A.

LCC reviewed groundwater monitoring data for IRP Site SD-11 and determined that TCE and *cis*-1,2-DCE were the only groundwater contaminants present in site groundwater at concentrations greater than their respective maximum contaminant levels (MCLs) (LCC, 1998). Groundwater contamination identified beneath former Oil/Water Separator A at the AGE Maintenance Area extends downgradient to the south.

Results obtained from previous site investigations performed at the AGE Maintenance Area of IRP Site SD-11 indicate that petroleum hydrocarbon contamination in vadose zone soils is primarily located in soils surrounding and beneath the pump island and former USTs, and immediately north of the concrete paved area. The pilot-scale bioventing system was designed, installed and operated to remediate petroleum contaminated soils in the immediate vicinity of the former USTs. The expanded bioventing system was designed and installed to also include petroleum contaminated soils north of and beneath the concrete paved area. Results of the April 1998 soil vapor sampling and respiration testing event indicate that BTEX contamination in soils treated by the bioventing system has been effectively reduced to non-detect or near non-detect levels. While some petroleum hydrocarbon contamination is still evident in soils near VMP3-24 and VMP4-10, the contaminants are not present at concentrations expected to pose significant site risk.

Confirmation soil sampling is recommended to demonstrate that no further site investigation or remediation of petroleum hydrocarbons is necessary in the area of the UST excavation and pump island. Confirmation soil sampling also is recommended north of the concrete paved area, near VW2, to determine if petroleum hydrocarbon contamination in this area has been adequately remediated. It is expected that fuel residuals have been adequately reduced by pilot-scale and expanded system bioventing and that existing petroleum hydrocarbon contaminant concentrations support a recommendation for NFI status. A specific sampling and analysis plan to support a NFI recommendation for petroleum hydrocarbon contamination at the IRP Site SD-11, AGE Maintenance Area is provided in Section 3. The criteria to be used for a NFI recommendation is provided in Section 4.

SECTION 3

SAMPLING AND ANALYSIS PLAN

The following SAP describes the sampling locations, sampling procedures, and analytical methods proposed to collect sufficient information to document the effectiveness of bioventing remediation of petroleum-hydrocarbon-contaminated soils in the AGE Maintenance Area of IRP Site SD-11 and support a recommendation of NFI for Tanks 1225.01, 1225.02, and 1225.03.

3.1 SOIL SAMPLING LOCATIONS

Confirmation soil samples will be collected from four soil borings located in the vicinity of the former USTs, pump island, and area north of the concrete paved area near VW2 (Figure 3.1). The four confirmation soil borings will be designated 11P001SB, 11P002SB, 11P003SB, and 11P004SB following the naming convention established during the site characterization.

The total depth of each soil boring will be determined based on multiple field observations (i.e., soil headspace screening and/or visual or physical evidence) which indicate the vertical extent of contamination has been adequately delineated. When field screening measurements indicate that the vertical extent of contamination in the soil boring has been adequately defined, a minimum of two soil samples will be collected for laboratory analysis and confirmation of the field measurements. If field measurements indicate that the vertical extent of contamination has not been adequately determined, soil sampling will continue as deep as necessary, but not beyond the depth of the groundwater surface (approximately 80 feet bgs).

The locations for two borings (11P001SB and 11P002SB) have been chosen in areas where soil concentrations of TPH greater than 2,000 mg/kg have been detected during prior investigations (i.e., adjacent to VW2 and adjacent to VMP2/11L002SB) (Tables 2.1 and 2.4). The third soil boring (11P003SB) has been located adjacent to the fuel pump island immediately east of the UST excavation. Elevated TPH concentrations measured in 1994 soil vapor samples collected at 11L023VP (37,700 ppmv) and 11L024VP (106,000 ppmv) (Table 2.3) are believed to be the result of vapor migration from petroleum-hydrocarbon-contaminated soils near the pump island during operation of the pilot-scale bioventing system. The fourth soil boring (11P004SB) will be located in the UST excavation area.

All four borings are within the estimated radius of influence of the bioventing system and are located near or within areas with previously detected BTEX or TPH in soil and soil vapor. If it is determined based on field observations that an additional soil boring is needed to adequately delineate the petroleum hydrocarbon contamination

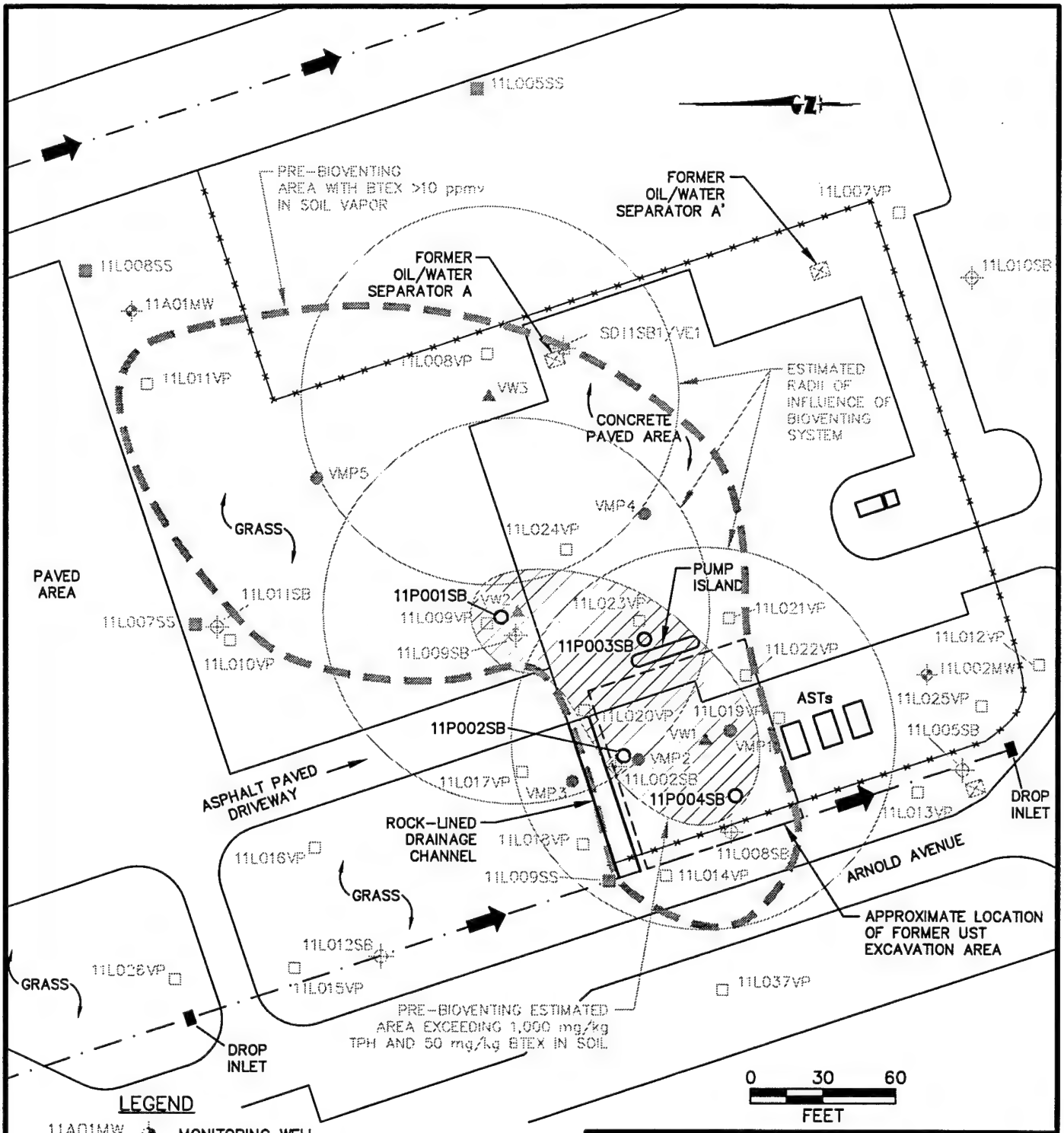

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FIGURE 3.1

PROPOSED CONFIRMATION SOIL SAMPLING LOCATIONS

IRP Site SD-11
AGE Maintenance Area
Beale AFB, California

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

remaining in site soils, a fifth soil boring may be installed. The purpose of the confirmation soil borings is to determine if petroleum hydrocarbon residuals in soil have been reduced sufficiently to allow a recommendation of NFI for the former USTs and petroleum hydrocarbon-contaminated soils located within the AGE Maintenance Area of IRP Site SD-11.

It is anticipated that at least three soil samples will be collected from each of the four borings for laboratory analyses in addition to two replicate samples (approximately 14 total samples). From each boring, one soil sample from the most contaminated sampling interval identified will be submitted for laboratory analysis. The remaining two samples will be collected at successive depths near the bottom of each boring where field screening measurements indicate no hydrocarbon contamination is present. Two samples will be collected to minimize the potential for unintentionally bypassing contamination due to changes in soil lithology. The final determination of the total number of samples and sample depths will be made based on field observations (i.e., soil headspace screening and/or visual or physical evidence). Soil samples will be collected and analyzed as described in Section 3.2 and Section 3.3, respectively.

3.2 SOIL SAMPLE COLLECTION

Boreholes will be advanced using a drill rig equipped with an 8-inch outside-diameter (OD) hollow-stem auger. Continuous coring of the borings will be conducted below 10 feet bgs in order to best select the intervals for sampling. Soil samples will be collected in a 2-inch inside-diameter (ID) split-barrel sampler. The sampler will be lowered through the hollow stem of the augers and driven approximately one to two feet into undisturbed soil ahead of the augers. The split-barrel sampler will be fitted with three pre-cleaned, 6-inch long, thin-walled, brass sleeves. After collection of a sample, the sampler will be retrieved, split apart, and the sleeves will be removed. The ends of the sleeves will be immediately capped with Teflon® tape and plastic endcaps. Samples will be labeled with the site name, borehole number, sample depth, and date and time of collection. The sleeves will be placed in an insulated shipping container with ice and will be maintained in a chilled condition.

A portion of soil from each split spoon will be used for soil headspace screening. Each headspace screening sample will be placed in a sealed plastic bag and allowed to sit in the shade for at least 5 minutes. Soil headspace will then be screened using a total volatile hydrocarbon analyzer (TVHA) and a photoionization detector (PID). The soil headspace reading will be used in combination with physical and visual evidence of contamination (e.g. odors, staining) to select samples for laboratory analysis. Soil samples selected for laboratory analysis will be shipped to Specialized Assays, Inc. (SAI), in Nashville, Tennessee. A chain-of-custody form will accompany all samples.

Boreholes will be logged by a Parsons ES geologist. The geologist will be responsible for observing all field investigation activities, maintaining a detailed descriptive log of all subsurface materials recovered during soil coring, and properly labeling and storing samples.

After sampling is complete, each sampling location will be restored as closely to its original condition as possible. Boreholes will be sealed with bentonite chips, pellets, or

grout to eliminate any creation or enhancement of contaminant migration pathways to the groundwater. Asphalt or concrete patch, as appropriate, will be used to finish surface completions.

3.3 SOIL SAMPLE ANALYSES

Soil samples will be analyzed by USEPA Method SW8015-modified for purgeable TPH-g and extractable TPH-d; by USEPA Method SW8020 for BTEX compounds; and by American Society for Testing and Materials (ASTM) D-2216 for soil moisture. Soil samples containing total TPH-d or total TPH-g also will be analyzed for soluble TPH-d using the waste extraction test (WET) preparation method described in California Administrative Code (CAC) Title 22, Article 11, Section 66700 (C through F) except that the extraction solution for the WET test shall consist of deionized water. In addition, a minimum of two soil samples will be collected from soils which do not appear to be impacted by petroleum hydrocarbon contamination (i.e., "clean soils") and analyzed for total organic carbon (TOC) content by USEPA Method SW9060 to support contaminant sorption evaluations.

Quality control (QC) samples also will be analyzed to assess laboratory methods. The laboratory will perform analyses on one matrix spike, one laboratory control sample, and one laboratory blank for each specific analytical method requested. Field QC samples will be collected and analyzed as described in Section 3.6.

3.4 SOIL VAPOR SAMPLING

Due to the high xylene concentration detected in soil vapor at VMP3-24 during the April 1998 Option 1 sampling event, confirmation soil vapor sampling will be performed at VMP3. Following 1 month of air extraction shut down at VW1 and VW2, soil vapor samples for field screening and laboratory analysis will be collected from VMP3-24, VMP3-30, and VMP3-40. Soil vapor samples for laboratory analysis will be submitted to Air Toxics, Ltd. in Folsom, California for analysis of TVH and BTEX by USEPA Method TO-3 referenced to jet fuel. Soil vapor samples will be used to assess xylene concentrations at VMP3-24 and assess BTEX concentrations with depth at this monitoring point.

3.5 EQUIPMENT DECONTAMINATION

All sampling and downhole equipment will be decontaminated before use and between boreholes to prevent cross-contamination. Prior to sample collection and between each sampling location, the soil sampler(s) and downhole sampling tools will be decontaminated using the following protocol:

- Clean with potable water and phosphate-free laboratory detergent (Alconox® or equivalent);
- Rinse with potable water;
- Rinse with distilled or deionized water;
- Rinse with isopropyl alcohol; and
- Air dry the equipment prior to use.

All decontamination fluids will be stored in 55-gallon US Department of Transportation (DOT)-approved drums provided by the driller.

3.6 FIELD QUALITY ASSURANCE/QUALITY CONTROL PROCEDURES

Field QC for soil will include collection of field replicates, rinseate blanks, and trip blanks. Soil QC sampling will include two replicates (minimum frequency of 10 percent); one rinseate blank; and one trip blank for each cooler submitted to the laboratory. Field replicates will be labeled in such a manner so that persons performing laboratory analyses are not able to distinguish replicates from other collected samples.

3.7 DISPOSAL OF INVESTIGATION DERIVED WASTE

All drill cuttings will be collected in labeled drums or bins after each borehole is drilled. Drill cuttings and decontamination fluids will be characterized prior to disposal. Characterization will determine the method of disposal in accordance with local regulatory and Beale AFB requirements. Parsons ES or its subcontractor will transport characterized drill cuttings and decontamination fluids to appropriate base disposal facilities, unless characterization results indicate that off-base disposal is required. Parsons ES will subcontract off-Base disposal of the drums, if necessary. Beale AFB will be responsible for providing their USEPA generator identification and signing the manifest prior to disposal.

SECTION 4

CRITERIA TO BE USED FOR NO FURTHER INVESTIGATION RECOMMENDATION

The recommendation for either NFI or further treatment of petroleum hydrocarbon-contaminated soils at the AGE Maintenance Area will be made based on an evaluation of the soil analytical results in accordance with principles set forth in the Risk-Based Cleanup Level Assessment (RBCLA) of Petroleum Contaminated Soils (Metcalf & Eddy, Inc., 1996). In addition, the Designated Level Methodology (DLM) (California Regional Water Quality Control Board [RWQCB], 1989), WQGs identified by the Cal/EPA (1998), and the California Leaking Underground Fuel Tank (LUFT) Guidelines (California State Water Resources Control Board, 1989) will be referenced in evaluating residual petroleum hydrocarbon contamination which may remain in site soils.

Specific characteristics of the Beale AFB RBCLA will be used in combination with site-specific soil and soil vapor analytical data to be collected in accordance with Section 3 of this SAP. The following information will be used to evaluate the potential impact to site groundwater and to determine the appropriateness of a NFI recommendation:

- Use of a depth to groundwater of 80 feet bgs (the AGE Maintenance Area is in Zone C/5 of the 16 separate geographic zones identified in the RBCLA);
- Use of a 1,000 μg/L soluble TPH-d target cleanup level, based on Table 5-2 from the RBCLA (Metcalf & Eddy, 1996), the DLM, and an environmental attenuation factor (EAF) of 100; and
- Use of soil vapor analytical data collected in accordance with Section 3.4 of this SAP as well as data from the April 1998 sampling event to document that BTEX contamination in the subsurface does not present a threat to groundwater.

4.1 TPH-D CLEANUP CRITERIA

The RBCLA has been established specifically for determining acceptable depths and concentrations of residual diesel-range petroleum hydrocarbon contamination in soils at Beale AFB. The soluble TPH-d cleanup criteria of 1,000 μg/L was established using an EAF of 100 for all geographic zones at Beale AFB based on the DLM and simulations of contaminant migration through the vadose zone using the USEPA Seasonal Soil Compartment Model (SESOIL). According to the DLM, an EAF of 100 should be used in those situations which provide an "average" degree of water quality protection (California RWQCB, 1989). At Beale AFB, the RBCLA demonstrated that

using an EAF of 100 to establish the target cleanup level for TPH-d is at the very least an "average" degree of groundwater protection considering typical depths to groundwater and SESOIL modeling results (Metcalf & Eddy, 1996).

The maximum allowable contaminant depth of TPH-d at the AGE Maintenance Area will be 58 feet bgs, as established for Zone C/5 in the RBCLA. Within this allowable contaminant depth for TPH-d, if total TPH-d or total TPH-g is detected, the soluble concentration of TPH-d will be compared to the target cleanup level of 1,000 μg/L. For contamination below the maximum allowable contaminant depth, the cleanup level is non-detect.

4.2 COMPLIANCE WITH BTEX SOIL VAPOR CRITERIA

No soil cleanup criteria similar to that established for TPH-d exist for the BTEX compounds. According to the RWQCB (1998), soil vapor criteria are used for the BTEX compounds in assessing site readiness for closure. The RWQCB (1998) soil vapor criteria are:

Benzene (ppmv)	Toluene (ppmv)	Ethylbenzene (ppmv)	Xylenes (ppmv)
0.071	3.037	2.161	1.231

A review of soil vapor analytical data collected during the April 1998 Option 1 soil vapor sampling event indicates that the xylene soil vapor concentration at VMP3-24 (14 ppmv) exceeded the criterion of 1.231 ppmv. At all other locations for which soil vapor samples were submitted for laboratory analysis, BTEX concentrations were less than the criteria shown (It should be noted that the soil vapor samples collected during the April 1998 sampling event were collected from the most contaminated VMP screened intervals based on field screening results). Near atmospheric oxygen concentrations in soil vapor at VMP3-30 and VMP3-40 as measured during the April 1998 sampling event indicate that it is unlikely that BTEX contaminants exceed the above criteria. However, confirmation soil vapor samples will be collected from the three screened intervals at VMP3 as discussed in Section 3.4.

4.3 OUT-OF-SCOPE VADOSE ZONE MODELING

Depending on the results of the soil and soil vapor sampling and the proposed evaluation, it may be necessary to perform more extensive, site-specific vadose zone modeling (using the SESOIL model) to determine the potential threat to groundwater quality or to demonstrate that any remaining soil residuals will not impact groundwater. Although input data necessary for such modeling will either be collected during the sampling and analysis described in Section 3 (e.g., contaminant concentrations, soil moisture, total organic carbon content), have been collected previously at the site (e.g., soil lithology, depth to groundwater), or have already been established for Beale AFB soils, additional vadose zone modeling is beyond the current contract scope.

SECTION 5

REPORT FORMAT

Following sampling activities and receipt of the laboratory analytical results, a results report will be prepared and submitted to AFCEE and Beale AFB, who will then forward the report to the local regulatory agencies.

The report will contain the following information:

- Site map showing sampling locations;
- Summary of field activities, procedures, and field screening and laboratory analytical results;
- Certified analytical laboratory reports and chain-of-custody forms;
- Borehole logs; and
- Conclusions and recommendations for either NFI or continued treatment of soils contaminated with petroleum hydrocarbons.

SECTION 6

PROJECT SCHEDULE

The following schedule assumes that this SAP will be submitted in its current form to the regulatory agencies.

DESCRIPTION	COMPLETION DATE
Draft SAP delivered to Beale AFB, AFCEE, and regulatory agencies	19 November 1998
All comments to draft SAP received by Parsons ES from Beale AFB, AFCEE, and regulatory agencies	7 December 1998
Soil boring locations marked by Parsons ES	7 December 1998
Final SAP delivered to Beale AFB, AFCEE, and regulatory agencies	22 December 1998
Digging permit due from Beale AFB	22 December 1998
Completion of drilling and soil sampling activities	8 January 1999
Draft results report delivered to Beale AFB and AFCEE	16 February 1999
Comments to draft results report due to Parsons ES from Beale AFB, AFCEE, and regulatory agencies	5 March 1999
Final results report delivered to Beale AFB, AFCEE, and regulatory agencies	19 March 1999

SECTION 7

POINTS OF CONTACT

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SECTION 8

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